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ABSTRACT

In this study, American pre-service teachers' responses on Kimball's Nature of Science Survey (NOSS) were used as a basis for analyzing the sense of "the nature of science" held by a group of Nigerian pre-service science teachers. In comparing the responses it was apparent that the Nigerian students were much more inclined to see science as a way of producing useful technology than were the American students. This tendency was attributed to government policies which view technology as needed for its country's development. The second distinction indicated in the study related to the "openness" of science. The Nigerian students perceived scientists to be nationalistic and secretive about their work. This conclusion is discussed in light of the tendency for developing nations to see science as a necessary stimulant for their country to compete economically in the world, and science teachers are seen to figure largely in this vision. Concerns are expressed about the image of Western science that is portrayed by the international media. (TW)

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A Cross-Cultural, Nature of Science Investigation: A Comparative Analysis of NOSS Profiles on Nigerian and American Pre-service, Secondary Science Teachers

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Fides Quaerens Intellectum

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ABSTRACT

In this study American pre-service science teachers' responses on Kimball's Nature of Science Survey (NOSS) were used as a basis for analyzing the sense of the nature of science held by a group of Nigerian pre-service science teachers. From an item by item comparison two salient differences were noted. These differences are quite interesting and important and one would expect to see replication attempts in the near future.

The primary difference was that the Nigerian students were much more inclined to see science as a way of producing useful technology. Given the national interests of a developing nation this is an understandable perception as well as a perception held by many government policy makers. Nevertheless, it is a view with potential long range dangers if this view of science is effectively transferred from teacher to student. For example such a view is likely to raise false expectations in the general population which when not achieved could result in widespread rejection of science.

The second distinctive of the Nigerian students' sense of the nature of science had to do with the openness of science. These students perceived scientists as nationalistic and secretive about their work. This finding is troubling and indicates an important line of investigation: what is the image of science, especially Western science, that is carried in the international media? how is that image understood in non-western nations? and what are the implications for international scientific cooperation?

Nigeria like most Third World nations sees science as a necessary stimulant for the economic development so urgently needed and sought. Quite naturally science teachers figure largely in this vision. The purpose of this study was to analyze Nigerian pre-service science teachers' sense of the nature of science using the responses of American students as a basis for comparison. Given that Nigerian teachers through contact with students play a crucial roll in influencing public opinion, it was anticipated that this study would provide important information for the on going debate over the role of science and science education in national development.

It is important to note that this was not a comparative study for the simple sake of comparison, nor for the purpose of pitting one national group against another. Nor is it implied that other nations should follow an American example. A study involving American students as a base for evaluating the orientation and magnitude of science education in developing nations is reasonable however, given the advanced state of science and technology in the United States and the large number of foreign students who study science and science education at American institutions of higher learning.

Theoretical Basis for Study

In 1951 James B. Conant wrote that it is not enough for one to be informed about science, but that one should also understand science. What was to be understood was the nature of science, i.e., its presuppositions, methods, structure, and limitations. Educators assumed that the teacher's notions about science influenced his students' understanding of science, and therefore it is important to evaluate the scientific understanding of both. Evaluations appeared in the 1950's literature by Wilson (1954) and Mead & Metraux (1957). Further research was stimulated by the theoretical work of Schwab (1960), Robinson (1968), and Martin (1972) who attempted to articulate the nature of science in such a way as to be useful for both education research and classroom practise.

In the three and a half decades following Conant's Science and Common Sense, researchers developed numerous instruments for assessing teachers' and students' knowledge of the nature of science. Comparative analyses of these instruments (see Doran, et. al., 1974; Lucas, 1975) reveal significant differences; and confirm Herron's 1969 comment that "...anything as complex as the nature of scientific knowledge, or 'inquiry,' is capable of being seen from a variety of points of view." (p. 106) Therefore, while one may say that the theoretical basis for nature of science research is well laid out in a plethora of published papers, it remains difficult to speak of the "nature of science" in common terms. Different researchers use different models; thus, the interpretation of research findings must always be presented in terms of the theoretical model employed.

This study employed the Kimball nature of science model which is thoroughly discussed in Kimball's 1967 paper. That discussion need not be repeated here. It suffices to present the model's eight points:

1. The fundamental driving force in science is curiosity concerning the physical universe. It has no connection with outcomes, applications, or uses aside from generation of new knowledge.

2. In the search for knowledge, science is process-oriented; dynamic, on-going activity rather than a static accumulation of information.

3. In dealing with knowledge as it is developed and manipulated, science aims at ever-increasing comprehensiveness and simplification, emphasizing mathematical language as the most precise and simplest means of stating relationships.

4. There is no one "scientific method" as often described in school science textbooks. Rather, there are as many methods of science as there are practitioners.

5. The methods of science are characterized by a few attributes which are more in the realm of values than techniques. Among these traits of science are dependence upon sense experience, insistence on operational definitions, recognition of the arbitrariness of definition and schemes of classification or organization, and the evaluation of scientific work in terms of reproducibility and of usefulness in furthering scientific inquiry.

6. A basic characteristic of science is a faith in the susceptibility of the physical universe to human ordering and understanding.

7. Science has a unique attribute of openness of mind, allowing for willingness to change opinion in the face of evidence, and the openness of the realm of investigation, unlimited by such factors as religion, politics, or geography.

8. Tentativeness and uncertainty mark all of science. Nothing is ever completely proven in science, and recognition of this fact is a guiding consideration of the discipline.

Based on these eight points, Kimball developed a 29-item scale called the Nature of Science Survey (NOSS). Each item is a statement with which subjects agree or disagree. They may also indicate uncertainty.

The reliability estimation and validation of NOSS for use with college students is described in detail by Kimball (1967). The results of further field testing have been published by Rubba & Andersen (1978), Rubba, Horner & Smith (1981), and Andersen, et. al., (1986).

Both Kimball in 1967, and Andersen (et. al.) in 1986, showed that the NOSS profiles of pre-service, science teachers did not differ significantly from the profiles of practising scientists. Because the published form of Kimball's data does not lend itself to comparative use, Andersen's student profiles were chosen for use as an analysis tool in the present study. His data is also more recent.

Procedure of Study

Subjects

The data used in this study was not collected as a part of a premeditated investigation. Between 1980 and 1983, the author routinely had his senior level pre-service science teachers at the University of Sokoto, Nigeria take NOSS as a way of introducing the subject of science philosophy and its relevance to the science classroom. As a stimulus to discussion, the data was compared with published data on American students. This report grew out of those discussions.

Method of Analysis

The NOSS items were scored by giving 3 points for responses in agreement with the model, 2 points for uncertainty, and 1 point for responses disagreeing with the model. Both item and test means were calculated. The item means formed a profile of the Nigerian students' understanding of the nature of science as described by Kimball. These

profiles were then compared with the published profiles of American students (Andersen, et. al., 1986). This procedure allows one to speak of similarities and differences in the specific terms of the theoretical model and avoids the ambiguous meaning of a "nature of science score." For further discussion on this procedural point see Aikenhead (1973) and Lucas (1975). The chart below gives the NOSS item numbers and the model points on which they are based:

NOSS Item Numbers	Model Points
4,8,12,23,24,25,29	1
11	2
7,10	3
1,3,9,13,15,17,21,27,28	4
2,16,19	5
6,14	6
18	7
5,20,22,26	8

The item means of the two groups were compared and all items with mean differences of 0.5 or greater were identified. The investigator made the a priori decision to set the selection criterion at 0.5 because that was deemed a minimum difference for practical significance. The identified items were then tested for statistical significance using t-tests (two-tailed at $p < 0.05$). That the N's for the two groups were different (Nigerians = 32; Americans = 21) posed some concern, since the item variances appeared to differ considerably (Hopkins & Glass, 1978, p. 238-9). All item variances were tested; and where the differences were significant, the Cochran variation was substituted for the standard t-test (Snedecor & Cochran, 1971, p. 115-6).

Kimball (1967), using the Spearman-Brown split-half formula, estimated the NOSS reliability to be 0.72. Andersen, et. al., (1986), reported an alpha internal consistency reliability coefficient of

0.74. In this study the Kuder-Richardson 20, reliability estimate was 0.71 (Cobern, 1986).

Results

The Nigerian data and the Andersen 1986 data are summarized in Table I. Table II gives the data for the eight items on which the two groups differed significantly. Of these eight items, five are associated with model point one, and one item each for model points four, seven and eight. There were no significant differences on the NOSS items associated with model points two, three, five and six.

There are thirteen NOSS items associated with model points four and eight (NOSS items 1,3,9,13,15,17,21,27,28 = point 4; NOSS items 5, 20,22,26 = point 8). That the student groups differed on only two of these items suggests that there is no significant disagreement on these two points. However, of the seven NOSS items that are associated with model point one, five discriminate between the two groups. It appears that the Nigerian students were much more inclined than their American counterparts to view the purpose of science in technological and development terms. In other words their sense of the nature of science was that science is primarily for the development of useful technology. There is some corroboration of this finding in Ogunniyi's study (1982, p. 31) in which he used several of Kimball's NOSS items. He found that 79% of the pre-service, science teachers sampled "...thought that the primary objective of a working scientist was to improve human welfare."

NOSS item 18 is associated with model point seven. It is the only item that raises the issue of nationalism, and thus is of special

NOSS ITEM RESULTS

Item	Model Response	American Students N=21 $\bar{X}_1$	Var	Nigerian Students N=32 $\bar{X}_2$	Var	$\bar{X}_2 - \bar{X}_1$	F Ratio*	t* Statistic
1. Most Important Scientific Ideas	D	1.60	.49	1.5	0.64	-0.1		
2. Scientists Classification Schemes	A	1.90	.81	1.7	0.64	-0.2		
3. Discoveries and Scientific Method	D	1.70	.64	1.4	0.49	-0.3		
4. Objective of Working Scientist	D	1.60	.81	1.3	0.49	-0.3		
5. Scientific Hypothesis and Data	D	2.10	.81	1.7	0.81	-0.4		
6. Scientific Investigation and Bias	D	2.50	.64	2.4	0.81	-0.1		
7. Science and Complex Knowledge	D	1.70	.81	1.3	0.49	-0.4		
8. Science and Practical Applications	D	2.00	.81	1.2	0.36	-0.8	2.25	-3.58
9. Deductive and Indirective Approaches	D	2.40	.36	2.1	0.64	-0.3		
10. Ultimate Goal of All Science	D	1.30	.49	1.6	0.64	+0.3		
11. Definition of Science	D	2.20	.81	1.8	0.81	-0.4		
12. Science and Mankind	D	2.20	.81	1.5	0.81	-0.7		-2.77
13. Teams of Scientific Researchers	D	2.30	.81	1.4	0.49	-0.9		-4.11
14. Invasion/Intrusion of Science	D	2.50	.64	2.3	0.81	-0.2		
15. Individual vs. Team Research	D	1.90	.64	1.8	0.64	-0.1		
16. Nature of Scientific Models	A	1.90	.81	1.7	0.81	-0.2		
17. Scientific Investigation Procedures	D	1.80	.81	1.8	0.81	0.0		
18. Sharing Scientific Findings	D	2.60	.49	1.8	0.81	-0.8		-4.93
19. Theories and Predictions	A	2.40	.64	2.4	0.81	0.0		
20. Universal Laws of Nature	D	1.80	.81	1.3	0.49	-0.5		-2.29
21. Steps of Scientific Method	D	1.20	.25	1.2	0.36	0.0		
22. Limitations of Science	A	2.20	.81	2.3	0.81	-0.1		
23. Science and Engines	D	2.30	.81	1.6	0.64	-0.7		-2.97
24. Science and Home Appliances	D	1.20	.16	1.3	0.49	+0.1		
25. Electrical Particles and Future	D	3.00	.04	2.3	0.64	-0.7	16.00	-4.73
26. Solving Scientific Problems	D	2.20	.81	2.1	1.00	-0.1		
27. Scientific Method and Myths	A	1.30	.36	1.5	0.64	+0.2		
28. Dedication for Scientific Work	D	2.30	.81	2.2	0.81	-0.1		
29. Characteristics of Science	D	2.10	.81	1.1	0.09	-1.0	9.00	-4.92
Total Score:		58.10	53.29	49.50	57.76	-8.6		-4.09

* $p < 0.05$

TABLE I

Item	Model Response	American Students N=21 $\bar{X}_1$	Var	Nigerian Students N=32 $\bar{X}_2$	Var	$\bar{X}_2 - \bar{X}_1$	F Ratio*	t* Statistic
8. A fundamental principle of science is that discoveries and research should have some practical applications	D	2.0	0.81	1.2	0.36	-0.8	2.25	-3.58
12. Science tries mainly to develop new machines and processes for the betterment of mankind	D	2.2	0.81	1.5	0.81	-0.7		-2.77
13. Any scientific research broader than a single specialty can only be carried out through the use of a team of researchers from various relevant fields	D	2.3	0.81	1.4	0.49	-0.9		-4.11
18. Most scientists are reluctant to foreigners, being mindful of the problem of national security	D	2.6	0.49	1.8	0.81	-0.8		-4.93
20. When a large number of observations have shown results consistent with a general rule, this generalization is considered to be a universal law of nature	D	1.8	0.81	1.3	0.49	-0.5		-2.29
23. The steam engine was one of the earliest and most important developments of modern science	D	2.3	0.81	1.6	0.64	-0.7		-2.97
25. If at some future date it is found that electricity does not consist of electrons, today's practices in designing electrical apparatus will have to be discarded	D	3.0	0.04	2.3	0.64	-0.7	16.00	-4.73
29. An important characteristic of the scientific enterprise is its emphasis on the practical	D	2.1	0.81	1.1	0.09	-1.0	9.00	-4.92
TOTAL SCORE:		58.10	53.29	49.5	57.76	-8.6		-4.09

* $p < 0.05$

TABLE II

interest in this study. In contrast to the American students, the Nigerian students did not accept the model position. The Nigerian students were inclined to see scientists as being quite nationalistic and secretive about their work.

Discussion

From its birth in 16th Century Europe, modern science has spread throughout Europe, to North America, to Japan and beyond. It began as a natural philosophy which had few practical implications. Not until the 20th Century did a relationship between science and technology become evident. Nevertheless, in Western societies pure, theoretical science is valued regardless of technological potential. Indeed, Western scientists give highest esteem to those colleagues engaged in pure science as opposed to applied science (e.g. see Wilson, 1984). Furthermore, pure science is generally considered an indispensable pre-requisite for any productive applied science endeavor (Powell, 1972), though there is considerable debate over the exact relationship between science and technology.

As science spreads from one geographical area to another, the new science is generally dependent upon old science for a period of time before independence. Science is independent in a new area when that area is able to train and support its own scientists, pursuing avenues of inquiry not dictated by scientists from other, older areas (for an in depth discussion of a model of the geographic spread of science, see Basalla, 1967). Sharing common roots and given much cross-fertilization, science tends to be similar no matter where it is found. Most scientists see similarity as conducive to the further

development of scientific knowledge. Thus, the finding of this study, that the Nigerian students viewed scientists as nationalistic and secretive, is cause for a degree of concern (bearing in mind that it is a weak finding, having its basis in only one test item). One wonders if such a view is a consequence of culture, education, or perhaps the international media's portrayal of science. The possible role of the media suggests an important avenue of research: what is the image of science, especially Western science, that is carried in the international media? how is that image understood in non-western societies? and what are the implications for international scientific cooperation?

Science and Development

The rise of science in the Third World nations began much as it did else where. However, the explosion of nationalism, exposure to science via a world-wide media, availability of financing either from the sale of commodities (especially oil) or international bank loans have altered the typical development path of science. In young nations like Nigeria, there is today far more scientific activity than would be anticipated by the Basalla model of scientific growth. Nigerian officials see that Western societies have used science and technology to enhance greatly their material well-being and international prestige (Abubakar, 1970). Faced with pressing human needs, they seek to do the same thing and as quickly as possible. Adopting the equation, science -> technology -> development, these governments have invested heavily in science, expecting substantial development returns.

A developing nation can make a prima facia case for supporting applied research in fields such as agriculture. Pure research is another matter. Many argue that pure research is too expensive (e.g., Haq, 1968). They argue that the results of pure research can be imported for use by indigenous scientists concentrating on applied research related to national needs; and may site Japan and Isreal as examples of nations who prospered following a similar strategy (e.g., see Drew, 1982). W. A. Lewis wrote at the beginning of the African independence movement:

> "Fortunately for the new states, they do not have to be in the forefront of developing new science. What they need is rather the application to their problems of what is already well known...
>
> Nevertheless, this existing body of science constitutes an immense contribution, freely offered by the older countries to the new." (see Powell, 1972, p. 402)

It can be inferred from the current investigation that the students who participated in the study are in agreement with this policy.

Such a policy has opponents however, who are quick to point out potential problems and adverse consequences (Menon, 1982; Salam, 1985). For example, developing nations risk failing to attain higher levels of international prestige and influence if they do not develop an independent science. They risk continued "brain-drain" to Western nations. Young scientists see no future for pure research in their homelands, so they flee to the West. And even those who stay at home to pursue applied research are apt to find that Western science is not always an adequate source for the information needed to fuel their applied science endeavors, as claimed by Lewis. Political action can at any time stop access to information, or the information may simply not be known. The latter is likely to be the case when the information concerns geographical areas remote from Western interests.

Furthermore, an acceptance of the "science -> technology -> development" equation with its accompanying emphasis of applied science, is apt to raise unrealistic expectations; unrealistic because there is more to technological development than a scientific base (see Harrison, 1985). And when these expectations are not realized, the scientific enterprise will suffer from a loss of public interest and support (a similar concern is expressed by Ogunyemi, 1969, p. 142-3). Finally, at the school level one must wonder what this emphasis does to the concept of "enquiry-teaching." Although it is not clear how much a teacher's own conception of the nature of science influences his teaching or his students' learning (e.g., see Lederman, 1985; Lederman & Zeidler, 1986), it would seem that an emphasis on the applications of science would lead to a teaching emphasis on the content of science at the expense of the processes of science. Western educators have fought this tendency for years. Should it be different in developing nations? The issues in this dilemma, the two sides of the nature of science debate, are elegantly expressed in these two quotes:

> "I come from a country...in which, while it is of great interest to talk about nuclear physics and fusion and all these things, it is of even greater interest to know how to save many of our babies...eight out of ten babies die before they are one year old. This is a very real question and one that has nothing to do with the building of nuclear reactors." (see Powell, 1972, p. 393)

> "Admonish me not, my beloved father, for forsaking you thus in your old age and sojourning here at Samarkand. It is not that I covet the musk melons and the grapes and the pomegranates of Samarkand; it is not the shades of the orchards on the banks of Zar-Afsham that keep me here. I love my native Kandhar and its tree-lined avenues even more and I pine to return. But forgive me, my exalted father, for my passion for knowledge. In Kandhar there are no scholars, no libraries, no quadrants, no astrolabes. My star-gazing excites nothing but ridicule and scorn...In my own town I am a sad, pathetic misfit." (see Salam, 1968)

Conclusion

The situation in most of the Third World is that the distribution between pure and applied research is more skewed to the applied side than in Western society (see Frame et. al., 1977). If the results of this study hold up, then one may conclude that Nigerian science teachers are reinforcing both this trend and a nationalistic notion of science. They may wish to continue doing so; but one would hope that it be a conscious decision based on an accurate knowledge of the scientific enterprise and its very complex relationship with technology.

The Nigerian Science Teachers Association encourages debate on these issues; but the debate is as well open to Westerners. First, because scientists and educators see themselves as a world-wide community. Second, because large numbers of Nigerian students and students from other developing nations study science, technology, and education in Western institutions.

PART II: Nigerian Science and Non-Science Students

At the time NOSS was given to Nigerian science students, a group of non-science students was also asked to take the survey. The data from the two groups is given in Table III. A rather startling discovery is that the science group did not do significantly better on the survey than the non-science group. Although it is tempting to say more about the results, one is restrained by the very low reliability estimate for the non-science group. The KR-20 estimate is 0.111 and the split-half estimates are only -0.069. There is virtually a zero correlation between the odd and even split halves of the surveys taken by the non-science students. Table IV shows the computer printout on the reliability estimates.

NIGERIAN SCIENCE AND NON-SCIENCE STUDENTS

Item	Model Response	Science Students N=21 $\bar{X}_1$	Var	Non-Science Students N=32 $\bar{X}_2$	Var	$\bar{X}_2 - \bar{X}_1$	F Ratio*	t* Statistic
1. Most Important Scientific Ideas	D	1.5	.64	1.6	.81	+0.1		
2. Scientists Classification Schemes	A	1.7	.64	2.0	1.00	+0.3		
3. Discoveries and Scientific Method	D	1.4	.49	1.2	.25	-0.2		
4. Objective of Working Scientist	D	1.3	.49	1.4	.64	+0.1		
5. Scientific Hypothesis and Data	D	1.7	.81	1.6	.81	-0.1		
6. Scientific Investigation and Bias	D	2.4	.81	2.1	1.00	-0.3		
7. Science and Complex Knowledge	D	1.3	.49	1.2	.36	-0.1		
8. Science and Practical Applications	D	1.2	.36	1.2	.25	0.0		
9. Deductive and Indirective Approaches	D	2.1	.64	2.3	.81	+0.2		
10. Ultimate Goal of All Science	D	1.6	.64	1.9	1.00	+0.3		
11. Definition of Science	D	1.8	.81	2.3	.81	+0.5		2.04
12. Science and Mankind	D	1.5	.81	1.7	.81	+0.2		
13. Teams of Scientific Researchers	D	1.4	.49	1.2	.36	-0.2		
14. Invasion/Intrusion of Science	D	2.3	.81	1.4	.81	-0.9		-3.66
15. Individual vs. Team Research	D	1.8	.64	1.2	.36	-0.6		-3.09
16. Nature of Scientific Models	A	1.7	.81	2.2	1.00	+0.5		-1.97
17. Scientific Investigation Procedures	D	1.8	.81	1.7	1.00	-0.1		
18. Sharing Scientific Findings	D	1.8	.64	1.6	.81	-0.2		
19. Theories and Predictions	A	2.4	.81	1.6	.81	-0.8		-3.26
20. Universal Laws of Nature	D	1.3	.49	1.6	.81	+0.3		
21. Steps of Scientific Method	D	1.2	.36	1.2	.49	0.0		
22. Limitations of Science	A	2.3	.81	2.2	1.00	-0.1		
23. Science and Engines	D	1.6	.64	1.7	.81	+0.1		
24. Science and Home Appliances	D	1.3	.49	1.2	.49	-0.1		
25. Electrical Particles and Future	D	2.3	.64	2.2	.81	-0.1		
26. Solving Scientific Problems	D	2.1	1.00	2.2	1.00	+0.1		
27. Scientific Method and Myths	A	1.5	.64	1.7	.81	+0.2		
28. Dedication for Scientific Work	D	2.2	.81	1.7	.81	-0.5		-2.04
29. Characteristics of Science	D	1.1	.09	1.2	.36	+0.1		
Total Score:		49.5	57.76	48.40	23.04	0.90	2.21	

* $p < 0.05$

TABLE III

RELIABILITY ESTIMATES ON SURVEYS TAKEN BY NON-SCIENCE STUDENTS

****
KUDER-RICHARDSON - 20 RELIABILITY COEFFICIENT
****

DATA FILE NAME a:d5fanoss

No. OF CASES READ 25

No. OF ITEMS 29

TEST VARIANCE = 24.423

SUM OF ITEM VARIANCES = 21.800

KR-20 = 0.111

****
SPLIT-HALF RELIABILITY COEFFICIENTS
****

DATA FILE NAME a:d5fanoss

No. OF CASES READ 25

No. OF ITEMS 29

S-ODD = 1.254

S-EVEN = 1.134

MEAN-ODD = 1.595

MEAN-EVEN = 1.751

COMMON SPLIT-HALF METHOD r = -0.069

RULON-GUTTMAN SPLIT-HALF METHOD r = -0.069

TABLE IV

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